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Analysis of Hazardous Material Incidents Reported to the Aviation Safety Reporting System

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ANALYSIS OF HAZARDOUS MATERIAL INCIDENTS REPORTED TO THE AVIATION SAFETY REPORTING SYSTEM

Robert O. Walton and P. Michael Politano

Abstract

Hazardous and dangerous goods are often shipped by air on both passenger and cargo aircraft. These hazardous materials (HAZMAT), also known as dangerous goods (DG), pose a danger to flight safety, passengers, and airline personnel. This research explored how effective the Aviation Safety Reporting System (ASRS) is at identifying aviation related HAZMAT incidents. Early identification of HAZMAT trends using the ASRS data could lead to changes in aviation safety monitoring and reduce the likelihood of a HAZMAT event causing an incident. This study identified prevalent categories of hazardous material found in reported incidents. The study further identified that most of the HAZMAT incidents involved cargo being flown on passenger aircraft and that two–thirds of the incidents were discovered after take-off. Missing or incorrect documentation was identified in approximately half of the cases. Statistical analysis of the data indicated that HAZMAT paperwork errors correlated significantly with damage to an aircraft and that the source of the problem (passenger carry on, passenger checked, cargo) correlated significantly with where (climb-out, landing, ground, cruise) the problems occurred.

Introduction

Purpose

This study examined the various types of hazardous material incidents that were reported to the ASRS database and conducted a trend analysis to determine if the ASRS database could be a valid source for determining the extent and type of hazardous material incidents. The purpose of this study was to better understand the type and prevalence of HAZMAT incidents that can affect flight safety. By identifying trends using the ASRS database, companies and regulatory agencies can focus rules and resources toward reducing these hazards and improve flight safety.

The Aviation Safety Reporting System

The Aviation Safety Reporting System (ASRS) was established in 1976 by the FAA, and uses NASA to act as the third party receiver of reports. The ASRS is a confidential reporting system used by pilots and other aviation personnel to identify potential safety hazards. The reporter is granted limited immunity from enforcement action for unintentional and non-criminal violations reported to the database within 10 days of the incident (Elliott & King, 2001). According to the NASA ASRS website, more than 715,000 reports have been submitted to the database since its inception in 1976. The intent of the database is to reduce aviation accidents and improve safety.

The data for this study were obtained from the NASA ASRS database. The database includes records from 1988 to 2008. Earlier data, from 1976 to 1987, were archived by NASA and are not available via public internet access. This research was conducted using the 20 years of available data from 1988 to 2008. NASA evaluates the data to eliminate duplicates, clarifies the reports and removes the identity of the reporter before posting the incident record to the database. Only incident data related to hazardous material were analyzed. One caveat on the ASRS database is that all ASRS reports are voluntarily submitted, and therefore for statistical purposes cannot be considered a random sample of the population and may show a reporting bias. The data in the ASRS database represents the lower bound estimate of the true number of events that have occurred. This study assumed that the reports to the ASRS database are true and accurate descriptions of the incidents.

Research Methodology

This research was conducted using a qualitative descriptive research method. The data were obtained by data mining the ASRS database. Since the data were submitted directly by the observer, it was considered primary data. The data were also examined using correlational analysis and multiple regression.

Treatment of Data and Procedures

A search of the ASRS database was conducted to extract the records associated with hazardous material. The search was optimized to reduce the number of false positives obtained by the electronic search. Key words such as HAZMAT or CHEM% were used to search for records associated with hazardous material incidents. The percentage mark (%) in the search string acts as a wild card and searches for derivations of words, e.g., for chemical, chemicals or chem., the search string CHEM% was used.

Once the search string was optimized, the ASRS database was searched and all hits exported to a Microsoft Excel spreadsheet. The database was then manually searched to eliminate all false positives that the automated search string did not eliminate. For example, a false positive may have included the 'overflow of the chemical toilet on board the aircraft.' The purpose of this study was to determine hazardous material carried as cargo, so, for example, an overflowing chemical toilet would be outside of the study boundaries.

Once the database was scrubbed to eliminate all false positives, the records were manually categorized and percentages were generated for each subcategory. The data were then reviewed to determine any trends that might appear. As noted earlier, the data reported to the ASRS are unconfirmed and voluntarily submitted and therefore, for statistical purposes, cannot be considered a random sampling of the population and may show a reporting bias.

Results

The initial search of the ASRS database using the search string of "HAZMAT or CHEM%" yielded 345 records. A further manual examination of the database, to eliminate false positives, narrowed the results to 176 records that related to reports of HAZMAT incidents. These 176 records were categorized and form the data set for this study. Figures one thorough five reveal the results of the data.

Figure 1 indicates the type of HAZMAT material involved in the reported incidents. The largest category was Other/NOS (not otherwise specified) at 28%. This proved to be the largest category because often the ASRS report narrative did not provide sufficient information to determine the type of material involved.

Many of the narratives only provided general statements about the event such as *fumes in the aircraft* or *spill of unknown substances*.

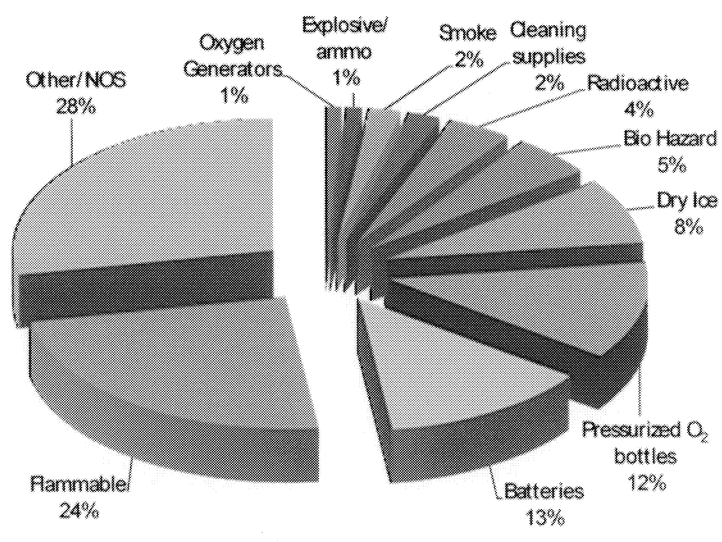

Figure 1. Type of material involved in HAZMAT incidents identified in the ASRS database from 1988 to 2008. Note: data obtained from ASRS, n.d.

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The second largest category was Volatile Organic Compounds (VOC)/flammable material at 24%. Flammable material or VOC's can consist of a number of hazardous substances such as gasoline, glue, or fingernail polish. VOC's can become very strong within a pressurized aircraft and could build to explosive levels. VOC's can also cause eye and throat irritation for the passengers and crew, requiring the crew to go onto oxygen or to divert the aircraft to an alternative airport.

Batteries were found to be the source of the problem in 13% of the ASRS HAZMAT cases. Improperly stored batteries can short out and cause sparks or fire, "lithium batteries fires cannot be extinguished by Halon 1301" ("Safe Shipments", 2004, p. 1). Most of the issues noted with batteries were improper storage of COMAT (Company Owned Material) or powered wheel chair batteries.

The fourth largest category was oxygen or other pressurized bottles at 12%. Pressurized bottles, if unsecured, can roll around in the cargo hold and become a projectile if the valve breaks. Oxygen also acts as an oxidizer and can accelerate an onboard fire. Oxygen has strict segregation requirements outlined in the segregation table of 49 Code of Federal Regulations (CFR) 177.848 to ensure that it does not come into contact with material that can start or accelerate an onboard fire (Transportation 49 C.F.R., 2003).

Dry ice was the next largest category at 8%. Dry ice is solid carbon dioxide and is often used in transportation to keep products cold. Dry ice sublimates directly to carbon dioxide which displaces oxygen and therefore must not be stored in the same cargo compartment with live animals or near the flight deck. Several of the HAZMAT incidents noted in the ASRS database required the diversion of aircraft because of improperly loaded dry ice.

Biological hazardous material such as organs for transplant or blood products was found in 5% of the cases, and radioactive material was found in 4%. Smoke in the aircraft from unknown sources and cleaning supplies, each caused 2% of the reported incidents. Explosives or ammunition was the cause of 1% of the incidents.

The improper shipment or storage of oxygen generators was found on two occasions (1%) in the ASRS database, once in January 1999 and then again in June 1999. Both of these events occurred three years after ValuJet Flight 592 crashed into the Florida Everglades due to the activation of oxygen generators in the cargo compartment. The narrative for these two incidents involving oxygen generators were submitted by maintenance personnel, and indicated little training in the proper shipment requirement for oxygen generators. In both cases, the reporter indicated pressure from supervisors to ship the generators.

Figure 2 shows the source of the HAZMAT material. Sixty percent of the reported HAZMAT incidents occurred while being carried as revenue generating cargo, either on a cargo aircraft or as belly cargo on passenger aircraft. Fifteen percent of the reports listed the source of the material as Company Owned Material (COMAT), most often being flown on passenger aircraft. Passenger checked luggage accounted for an additional 15% of the reported incidents. The smallest group was passenger carry on at 10% of the incidents; two of the reported incidents occurred after the Transportation Security Administration (TSA) stepped up screening methods following September 11, 2001.

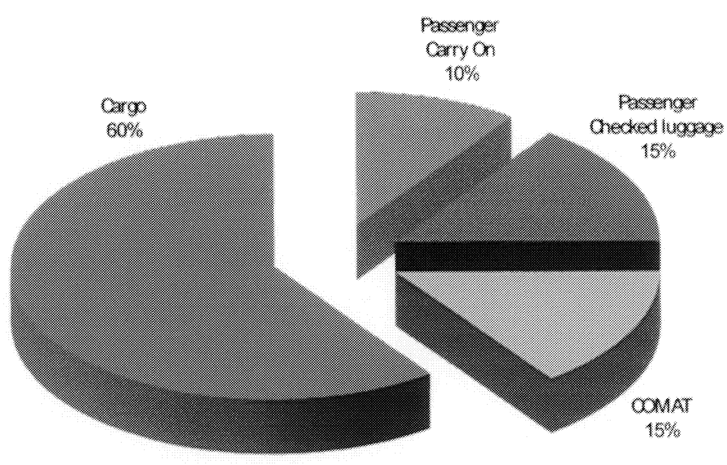

Figure 2. Source of the material involved in HAZMAT incidents identified in the ASRS database from 1988 to 2008. Note: data obtained from ASRS, n.d.

Figure 3 shows the type of aircraft involved in the incident. Fifty-three percent of the reported incidents occurred on passenger aircraft with 13% taking place on an all-cargo aircraft. The type of aircraft involved could not be determined in 34% of the cases.

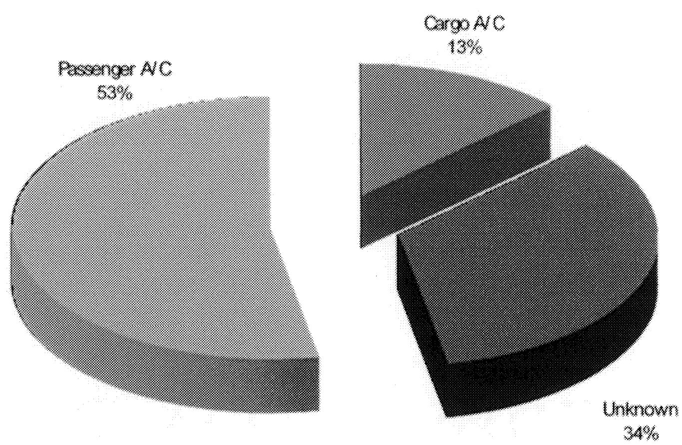

Figure 3. Type of aircraft involved in HAZMAT incidents as identified in the ASRS database from 1988 to 2008. Note: data obtained from ASRS, n.d.

The point in flight operations, when the discovery of an HAZMAT incident had occurred (Figure 4), was fairly evenly split between loading (34%), in-flight (36%) and after landing (30%). The best point to discover a HAZMAT problem is before the flight departs so that the issue can be resolved before it causes a flight safety problem. If the problem is discovered while in-flight it can sometimes require the aircraft to divert to an alternate airport. The ASRS database showed that in-flight diversions were required in over one third of the incidents, for a total of 23 diversions between 1988 and 2008 . Diversions can cost airlines from $3,000 to more than $100,000 depending on when they occur (Chandler, 2006). Therefore, it can be assumed that the 23 diversions that were reported due to HAZMAT issues cost the airlines between $69,000 and $2.3 million. However, since the ASRA data are considered a lower bound estimate, the actual number of diversions, and attributed cost, can be assumed to be higher. Thirty percent of the incidents were discovered after landing, indicating that in 30% of the cases HAZMAT may have endangered flight safety.

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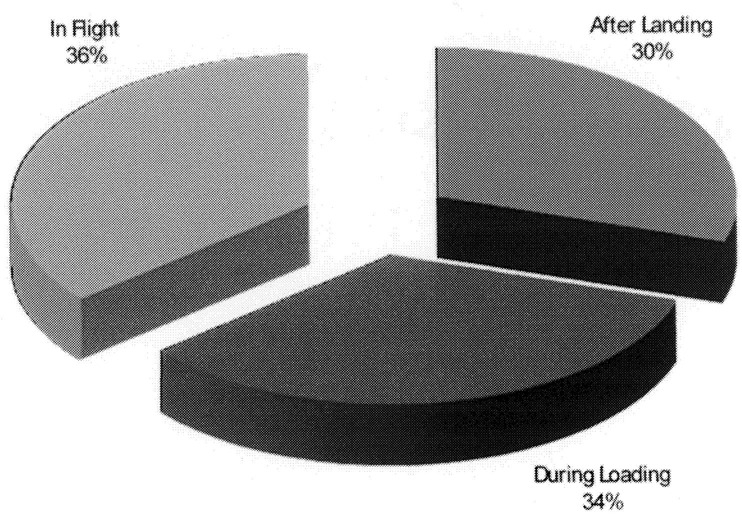

Figure 4. Point of flight operations when discovery of HAZMAT incident occurred as identified in the ASRS database from 1988 to 2008. Note: data obtained from ASRS, n.d.

Figure 5 shows the type of violation of HAZMAT rules. These violations are a mix of U.S. Federal regulations listed under 49 CFR (Transportation 49 C.F.R., 2003), internationally promulgated rules outlined in the International Civil Aviation Organization (ICAO) technical instruction for safe transport of dangerous goods by air or under internal company rules.

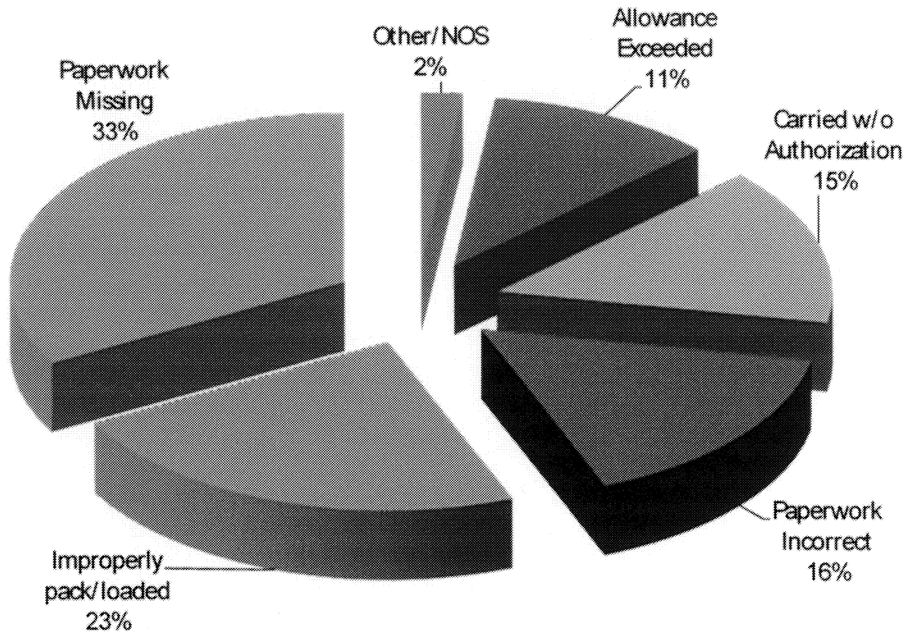

Figure 5. Violation of HAZMAT rules for incidents identified in the ASRS database from 1988 to 2008. Note: data obtained from ASRS, n.d.

In 49% of the cases, the required documentation was either missing or incorrectly completed. Incorrectly completed documentation issues normally resulted in improperly listed material or quantities. This resulted in the aircrew not knowing what type of material was onboard. The pilot has overall responsibility for the aircraft and what is being carried onboard. If the paperwork is missing or incorrect, the pilot may not have the required information needed in an emergency. Fifteen percent of the ASRS records revealed that hazardous material was carried without authorization, because either the pilot was not informed of the material onboard or the material, by regulation was not allowed to be flown on an aircraft, either cargo and or passenger. Additionally 11% of the time, the type of HAZMAT exceeded the maximum allowance to be carried on an aircraft as outlined by regulation.

Improperly packaged or loaded material was reported in 23% of the incidents. Fifty-five reports of improperly packaged or loaded HAZMAT were reported to the ASRS from 1988 to 2008, with 47 of these discovered after a leak had occurred.

Statistical Analysis

A multiple regression analysis using a Stepwise entry was conducted, which revealed that the only variable predictive of damage was paperwork errors (R=.26, R^2=.06, $F(2,160)=11.29, p<.001$). None of the other variables (time-

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zone of flight, light conditions, altitude, visual or instrument operation, source of the problem as in carry-on or checked baggage, location of the aircraft at the time the problem occurred, for example, in flight or on the ground, type of material involved) met the threshold for inclusion (.05) in the regression equation.

However, there were some significant correlations among the variables themselves: Whether the aircraft was on visual or instrument correlated significantly with altitude and light conditions (r=.43 and .26, respectively, p<.001). Paperwork errors correlated significantly with damage (r=.26, p<.01). The source of the problem (passenger carry on, passenger checked, cargo) correlated significantly with where (climb-out, landing, ground, cruise) the problems occurred (r=.17, p<.05)—this is a small correlation and is significant only because N=163.

Conclusions

The movement of HAZMAT on aircraft can be dangerous to flight safety but is vital in today's economy and therefore will continue in the future. Methods to reduce hazards posed by the movement of HAZMAT on aircraft must continue to improve to ensure flight safety for passengers and crew. The ASRS database can provide historical insight into the improper transportation of hazardous material on aircraft, and should be used as one of many tools in improving flight safety.

Based on the research conducted, VOC or flammable material, batteries, and oxygen or pressurized bottles were identified as the cause in 49% of all incidents reported to the ASRS database. By focusing on reducing incidents of these categories, the overall number of HAZMAT incidents may be greatly reduced.

Figure 2 shows that 60% of the HAZMAT incidents occur in revenue generating cargo, and Figure 3 shows over 53% of the incidents occurred on passenger aircraft. In this area, the greatest improvement to flight safety would result by reducing the HAZMAT incidents associated with cargo being flown on passenger aircraft. This may require additional cargo screening and education of both shippers and ground handling personnel.

According to the ASRS database, 70% of HAZMAT incidents are discovered after the aircraft has become airborne, too late to ensure flight safety. When HAZMAT issues are discovered in flight, one-third of these lead to a flight diversion, costing the airline tens of thousands of dollars per diversion or a possible incident or accident. Statistical analysis of the date showed that the source of the problem (passenger carry on, passenger checked, cargo) correlated significantly with where (climb-out, landing, ground, cruise) the problems occurred.

Missing or incorrect documentation was found in 49% of the incidents. In itself, this may not cause a HAZMAT incident, but it can affect flight safety when the flight crew is not properly advised as to the type of material being carried. Missing or incorrect documentation may also indicate a lax attitude toward the movement of hazardous material on aircraft. Statistical analysis of the data showed that paperwork errors correlated significantly with damage.

Based on the research conducted, 23% of the incidents were caused by improperly packaged or loaded hazardous material. Unlike the missing or incorrect documentation, the mishandling of HAZMAT has a direct impact on flight safety. Forty-seven of the 55 records associated with improperly packaged or loaded goods indicated leakage and, therefore, potentially directly affected flight safety. Twenty-six percent of the incidents involved the transport of HAZMAT, either in excess of the allowance limit or without proper authorization. Often times a lack of training was noted in the ASRS database for this failure.

As this research has suggested, the ASRS database can be used for a trend analysis of HAZMAT incidents on aircraft. The result of a trend analysis may reduce the number of future HAZMAT incidents and improve flight safety. By utilizing trend analysis of the ASRS database, both corporations and governments can decide where to focus their limited resources to improve flight safety.

Recommendations

The FAA and airlines have limited resources and thus must focus their efforts to ensure that flight safety is maintained at a reasonable cost. Based on the research outlined in this study, the ASRS database identified several areas that the FAA and airlines should focus on, namely, education, inspection, and enforcement activities as they relate to HAZMAT issues. The following recommendations are based on the research conducted and conclusions stated above.

The FAA and airlines should focus their efforts on all HAZMAT being transported. Training by the airlines should be focusing on the proper shipment of VOC's, flammable material, batteries, and oxygen or pressurized bottles, thus potentially reducing the overall number of HAZMAT incidents. Further, FAA efforts to improved screening of cargo being flown on passenger aircraft may reduce the amount of improperly shipped or loaded

HAZMAT and therefore increase flight safety.

The FAA and airlines should also focus their efforts on ensuring that all HAZMAT is properly documented, packaged, and loaded on the aircraft and that the flight crews are fully and accurately informed about the materials they are carrying. The FAA may consider some type of certification or licensing program for ground handlers and the airlines should develop or expand their training of ground handlers. This may require additional cargo screening and education programs for shippers and ground handling personnel as well as flight crews.

This research is limited to HAZMAT issues found in the ASRS database; however, the database can be used for trend analysis for other flight issues. Further research should be conducted using the ASRS database to identify other flight safety issues.✈

Robert Walton holds a Master of Business Administration and a Master of Aeronautical Science and is completing work on a Ph.D in Business Administration. Robert teaches and conducts research on various aeronautical and related subjects at Embry-Riddle Aeronautical University – Worldwide.

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